OFFICE OF NAVAL RESEARCH – NAVY MANTECH

THE CENTER FOR NAVAL SHIPBUILDING TECHNOLOGY

CAPABILITIES STUDY OF MID-TIER U.S. SHIPYARDS

Abbreviated industry report

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Abbreviated industry capabilities report

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NOTE:

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0 SUMMARY AND PRINCIPAL CONCLUSIONS

In 2005, the Office of Naval Research (ONR) commissioned a study of mid-tier U.S. shipyards to assess their capability to build medium-sized combatants. The study was executed through ONR's Navy ManTech Center of Excellence, the Center for Naval Shipbuilding Technology (CNST). To reduce cost and the impact on the shipyards, the assessment was combined with Part 2 of the Global Shipbuilding Industrial Base Benchmarking Study (GSIBBS) being carried out by the Office of the Deputy Under Secretary of Defense (Industrial Policy) (ODUSD(IP)). Proprietary shipyard reports for both parts of the study have been produced for each of the nine participating shipyards surveyed. This report summarizes the findings of the capabilities assessment of seven mid-tier shipyards that are considered to be representative of the industry as a whole. First Marine International (FMI) carried out the shipyard surveys with assistance from CNST and observers from ODUSD(IP).

The capability of the yards was assessed using a tool created specifically for the study by CNST and FMI. Sixty-three elements of naval ship design and construction, grouped into ten functional areas, have been considered. Figure 0.1 shows the range and average capability ratings assigned across the shipyards surveyed. A score of 0.0 indicates no capability and 2.0 a full capability. To be considered to have a full capability in a particular element, the processes and practice applied need to be relatively up-to-date and to be in accordance with good practice. For each group, the left-hand end of the line represents the lowest individual yard average score, the right-hand end the highest, and the middle line the average for all yards.

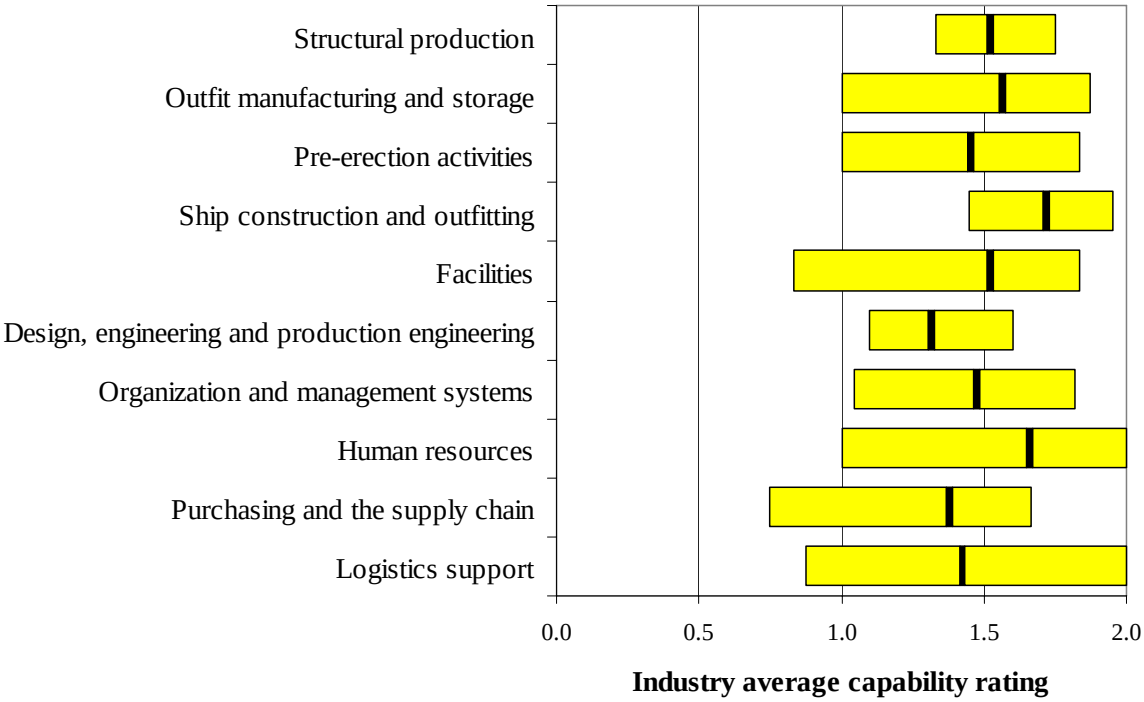

Figure 0.1 – Overall industry capability ratings

Building a 400ft medium-sized combatant is at the upper limit of what is realistically possible in most of the shipyards surveyed. However, facilities and equipment upgrades would be required in some yards. In order to achieve a good level of productivity and minimize the risk of cost and schedule overruns, changes would be necessary in most element groups in most yards. This is particularly the case in the elements where there are large differences between commercial and military practice. There are also areas where increased ship complexity would require some of the yards to change their current practices and systems. These include planning systems, particularly outfit planning, and management organization. Most yards have a highly competent technical department but they have relatively low capacity when compared to what is generally available in a naval yard and they have limited knowledge of naval vessels.

Most yards would have to increase the number of tradesmen to build combatants in a reasonable time and in some cases change the mix of trades to build higher outfit ratio vessels. They would also require additional non-touch labor. Individual members of the management and workforce in this sector have far less experience of naval new construction than their first-tier counterparts. However, a high proportion of personnel have built for the Coast Guard or have undertaken naval repairs within their current employment. Many also have some previous experience with naval construction.

There is a moderate degree of subcontracting in the mid-tier yards. The highest incidences occur in outfit manufacturing and storage, design, engineering and production engineering, and logistics support. The capability provided by subcontractors is important when considering the capability of individual shipyards and the sector as a whole. However, this is not reflected in the shipyard scores. Prime contractors that may be involved in the construction of naval vessels can add significantly to the capability of a mid-tier shipyard and, again, this has not been reflected in the shipyard scores.

A high-level capacity model has been used to obtain a rough order of magnitude indication of the capacity of the yards surveyed. The model indicates that their capacity is mainly limited by human resources. At the current level of employment, the combined capacity of the seven yards is just over five typical medium-sized combatants per annum at steady-state, with each yard able to build between 0.3 and 1.3 ships per annum. Without the labor constraint, the capacity would increase to more than seven vessels per annum at steady-state. However, it should be noted that there is a limited pool of suitable labor and the majority of yards are currently recruiting nation wide. At this level of output, most yards would be limited by their steel preparation and assembly areas and the capacity of some outfit manufacturing shops.

1 INTRODUCTION

1.1 Background

The Office of the Deputy Under Secretary of Defense (Industrial Policy) (ODUSD(IP)) recently completed Part 1 of a Global Shipbuilding Industrial Base Benchmarking Study (GSIBBS) that was focused on the first-tier U.S. shipyards and leading large international yards. Part 1 had several objectives but the principal output was a proposed list of actions for the Department of Defense and Industry to improve the performance of the U.S. shipbuilding enterprise. ODUSD(IP) has extended GSIBBS to include the U.S. mid-tier yards (Part 2).

At approximately the same time, the Office of Naval Research (ONR) commissioned a study of mid-tier U.S. shipyards to assess their capability to build medium-sized combatants. The study has been executed through its Navy ManTech Center of Excellence, the Center for Naval Shipbuilding Technology (CNST). The functions of both ODUSD(IP) and CNST are described in Appendix 1.

The capabilities assessment and benchmarking study have common elements and a similar methodology. Therefore, in order to make the most efficient use of resources and minimize industry disruption, the two studies were combined and carried out simultaneously.

The overall objectives of the combined study were to:

- Understand the capabilities of mid-tier U.S. shipyards to design and build medium-sized naval combatants made of thin steel or aluminum in accordance with U.S. Navy requirements and ABS Naval Vessel Rules.
- Compare the practices of mid-tier U.S. and selected international commercial and naval shipbuilders in Europe and Australia.
- Identify specific changes to mid-tier U.S. shipbuilding industry processes and to U.S. naval design and acquisition practices that will improve the performance of the shipbuilding enterprise.
- Guide future investment (ManTech, NSRP, etc.).
- Provide participating shipyards with an independent assessment of the current status of their processes, practices and performance in an international context.

First Marine International (FMI) carried out shipyard surveys to gather the required information with assistance from ODUSD(IP) and CNST. This report records FMI's findings for the capabilities part of the study. The benchmarking aspects are covered in a separate report.

The capability of the yards has been assessed using a tool created specifically for the study by CNST and FMI. The tool is described in Section 1.3. The assessment also includes a high-level review of the capacity of the mid-tier shipyards using a model developed by FMI.

Each participating U.S. shipyard has received three proprietary reports. The first relates to the benchmarking aspects and defines the processes and practices within the yard, compares them with international best practice and makes suggestions for improvement actions. The second presents the

findings of the capability survey and capacity analysis but does not suggest remedies. The third, which was produced after the surveys of the international and U.S. yards were completed, presents a prioritized list of action areas. The foreign participating yards received a benchmarking report only.

1.2 Approach to the study

A more detailed explanation of the methods used has been included in the relevant sections of this report. A summary of the approach is as follows:

1. Survey ten functional areas of manufacturing and business processes and practices (sixty-three elements in total) of a representative sample of nine mid-tier U.S. shipyards.
2. Estimate the capacity of each shipyard using a high-level model.
3. Write a confidential report for each shipyard describing its capabilities.
4. Aggregate the individual shipyard findings to industry level to understand the capabilities and capacity of the U.S. mid-tier yards as a whole.
5. Present the general findings in an overall report.

In order to avoid duplication of effort and minimize shipyard disruption, the data to complete both aspects of the study was gathered during a two-day visit to each yard. The survey team comprised two or three FMI consultants, representatives of CNST who assisted with the surveys and writing the reports, and observers from ODUSD(IP).

The findings summarized in this report are based on the information provided to the consultants by the shipyards. While it has been possible to validate a significant proportion of this information by inspection, this has not been possible in all cases.

For the purposes of this capabilities study, two of the nine shipyards surveyed were not considered typical mid-tier shipyards in terms of size and/or product mix. These yards have therefore been excluded from the industry capability and capacity analyses.

1.3 The capabilities assessment tool

The aspects of shipyard capability considered have been grouped into the following ten functional areas:

- Structural production
- Outfit manufacturing and storage
- Pre-erection activities
- Ship construction and outfitting
- Facilities
- Design, engineering and production engineering
- Organization and management systems
- Human resources
- Purchasing and the supply chain
- Logistics support

Each area is further broken down into individual elements, sixty-three in total. The analysis assumes that each shipyard has already demonstrated its capability to build commercial ships. Therefore, the elements reviewed are those for which additional capabilities are required to design and build medium-sized naval combatants. Each element is scored to reflect the surveyors' understanding of the capability. The scoring system used ranges from 0 to 2 in half-point increments and indicates the status of each element as follows:

Score	Definition
2	The yard has full capability for that element.
1	The shipyard has some capability and, with a moderate effort, could develop the necessary capability.
0	The yard has no, or close to no capability or experience.

Table 1.1 – Definition of element scores

The capability to be assessed is defined for each element, as are the key indicators that are used to determine the status of the capability. The capability indicators are not regarded as comprehensive and consideration of the score for each element has not been limited solely to the status of the indicators, it has also relied on the observations of the surveyor. In order to be considered to have a full capability in some element groups, a yard needs to carry out work in a manner that is in accordance with appropriate, modern shipbuilding practice. Thus, low scores can indicate that a shipyard is physically capable of carrying out the work but either its productivity is low, or it would have difficulty staying on schedule or within cost, especially on a first-of-class.

If the capability for an entire element in a shipyard is provided by a subcontractor then the element is scored as "S" and it does not contribute to the overall score for the yard. Partial subcontracting has also been recorded.

1.4 Presentation of industry findings

Section 2 summarizes the findings by group in the shipyard sample as a whole. Sections 3 to 12 in the full report, which is available from CNST, summarize the findings for each element. A graph shows the range of scores and averages for each element. The definition of the capability is included under each element as are the key capability indicators. The status of the key capability indicators for the whole shipyard sample, in terms of proportion of shipyards, is shown. A comment that characterizes the status of the indicator across the sample has been included, as has an overall comment (where appropriate) regarding each element. The proportion of yards that subcontract all or part of the work covered by the element is also shown.

2 OVERALL FINDINGS

2.1 Capabilities scores

Figure 2.1 shows the range of capability ratings assigned by element group across all of the shipyards surveyed. For each group, the left-hand end of the line represents the lowest individual yard average score, the right-hand end the highest, and the middle line is the average for all yards.

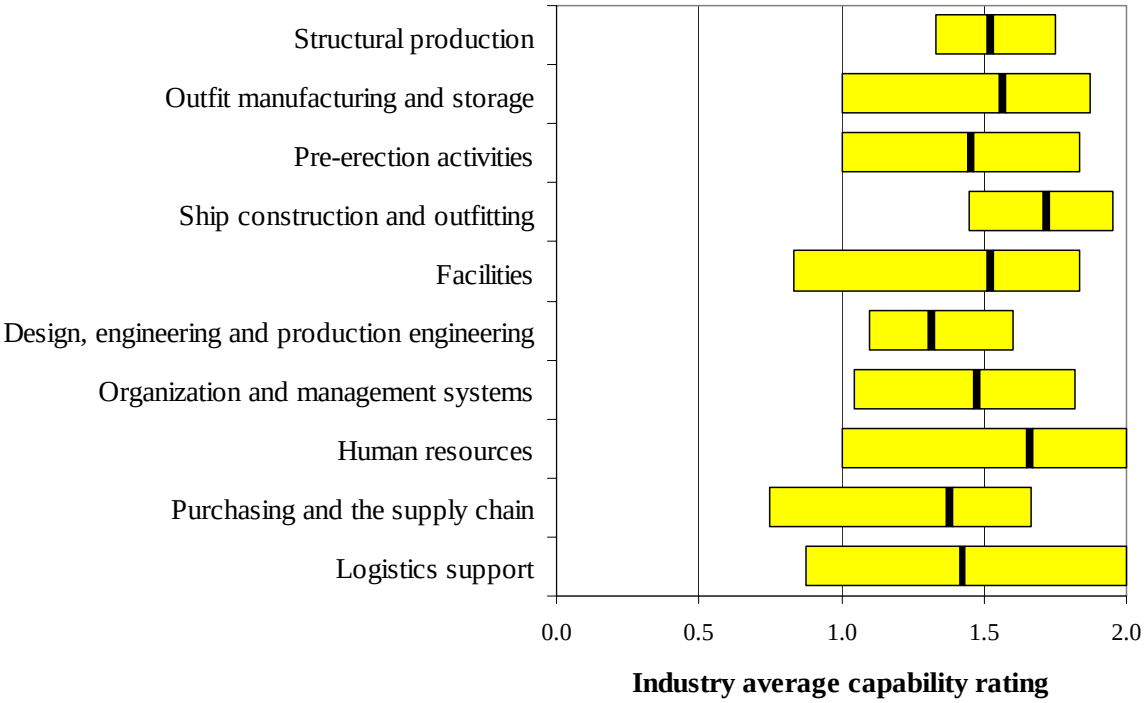

Figure 2.1 – Overall industry capability ratings

2.2 Capabilities overview

Building a 400ft medium-sized combatant is at the upper limit of what is realistically possible in most of the shipyards surveyed. However, facilities and equipment upgrades would be required in some yards. In order to achieve a good level of productivity and minimize the risk of cost and schedule overruns, changes would be necessary in most element groups in most yards. This is particularly the case in the elements where there are large differences between commercial and military practice. There are also areas where increased ship complexity would require some of the yards to change their current practices and systems. These include planning systems, particularly outfit planning, and management organization. Most yards have a highly competent technical department but they have relatively low capacity when compared to what is generally available in a naval yard and they have limited knowledge of naval vessels.

2.3 Structural production

One yard has a system of just-in-time delivery for plates but most maintain a stockyard. A number of yards purchase pre-primed plates and stiffeners but most prime their own either using a blast and paint line or a painting cell or area. The way plates and stiffeners are stored and handled in some stockyards and treatment lines tends to induce stress which may result in distortion. Plate cutting is generally done in-house and is satisfactory. All yards use plasma cutting but some old oxy-gas machines are used for thicker plates. One yard has made excellent use of laser cutting. A combination of sawing and oxy-gas cutting is normally used for stiffener cutting and the methods would benefit from being upgraded in all but one yard. This is particularly the case for T-beam preparation. The equipment available to form single curvature plates is appropriate but there is almost no heat-line bending in use and, in the steel yards, there is a limited amount of equipment available to form plates with more complex curvature. This work is often subcontracted.

Only a few steel/aluminum assembly facilities incorporate mechanized lines for flat panel production and, in some yards, workstation definition is poor or non-existent. Separate facilities or workstations for assembling aluminum are not always available in the steel yards but, although some subcontract this work, all yards have a proven track record in working with this material and dealing with the steel/ aluminum interface. The yards are used to constructing vessels from relatively light scantling materials and some claim to be leaders in this field. However, the scantlings are generally not as light as could be expected on some combatants and the study has shown that more could be done in some yards to control dimensions and reduce distortion. Welding is generally semi-automatic in assembly. No laser welding was seen. Although the yards have worked with high strength steels and are familiar with heat treatment requirements, there was no evidence of such steels being used at the time of the surveys.

2.4 Outfit manufacturing and storage

There is experience in dealing with military requirements for outfit systems in the majority of yards although, in some, the experience has been gained through Coast Guard work or ship repair. All the yards surveyed have a pipe shop of some type but generally they have limited capacity in terms of throughput and the size of pipes that can be bent. A large proportion of pipes, especially small bore, tend to be ship lifted or field run. Welded elbows are used extensively in some yards. Other than titanium, in which there is limited experience, all yards have dealt with the types of pipes that could be expected on combatants. Most have a basic machine shop but complex tasks are normally subcontracted. This can include the machining of foundations on-board and boring shaft lines. The manufacture of electrical items such as switchboards and junction boxes is usually subcontracted as is some electrical installation and specialist electronics work.

One yard has a good sheet metal manufacturing capability but the majority of sheet metal manufacture and fiber reinforced plastic production is subcontracted. There is considered to be sufficient general storage area in all yards but there is limited environmentally controlled storage available. In some there may not be sufficient space to manage and collate a large volume of on-board spares. Warehouse security would need to be upgraded in about half the yards. The collation and maintenance of materials and equipment certificates is common practice although it is sometimes subcontracted.

2.5 Pre-erection activities

Most yards have the space to construct and outfit blocks but not necessarily undercover. Although it is still at a low level in some yards, there can be a relatively high level of pre-erection outfitting achieved, even on a first-of-class. Permanent environmental protection for block construction is not available in all yards and some make insufficient use of temporary protection. There are poor ground conditions for block construction and storage in most yards. There is usually ample open space within shipyard boundaries, so unit and block storage areas are likely to be adequate for all future needs but, again, temporary environmental protection would be required. Contractors would be required to move very large blocks in some yards.

Most yards have suitable equipment for handling manufactured components without inducing distortion but some rely on the skills of the production workforce with no technical guidance to achieve this.

2.6 Ship construction and outfitting

All the yards have sufficient space to construct vessels up to 400ft in length although this is often the limit of their capability. Three of the yards surveyed have an undercover construction point and a fourth is considering developing one. There is limited availability of building berths that conform to MIL-STD 1625 and two yards would need to carry out civil engineering works to launch a 400ft vessel. In those that can currently launch such a vessel, the method of launching is split between side launching and load-out onto a floating dock or barge. The yards are aware of the required dimensional quality standard and have successfully constructed vessels to this standard. Dimensional control methods tend to be simple and there would be benefit in increasing the use of 3D measurement systems.

Most yards are capable of building vessels from relatively large modules and blocks and some would be able to load-out/load-in blocks without civil engineering works. Welding processes are generally up to the required standard although more work is needed on developing welding sequences to reduce distortion. Provision of the necessary temporary services would not be a problem in any of the yards, although there would be benefit in making more effort to pre-plan their use and in developing build strategies that require fewer temporary services to support production. That said, considerable efforts have been made to ensure that the need for staging and temporary access is minimized.

Generally, painting conditions are acceptable although some yards rely on temporary facilities to provide environmental controls. There is a demonstrated capability throughout the industry to install, test and evaluate all types of outfit including the more specialized control and communications systems. However, this is often achieved by subcontracting work to equipment suppliers or specialist companies.

2.7 Facilities

In addition to having sufficient land area, there is adequate alongside berthing for final outfit and commissioning in most yards but some civil works would be required in a few. In one yard, icing means that there are limited windows for ship movements and, in another, there could be a problem with air draught which may require vessels to be completed and trialed at another facility. Other than

these, there do not appear to be any navigational constraints. There is a high proportion of unpaved roads, partly the result of the extensive use of crawler cranes. This means that the movement of very large blocks can be difficult and that the conditions are not conducive to a clean and tidy working environment. With the exception of ship construction, undercover working is the norm, although there is a shortage of covered assembly areas in a number of yards, particularly for block construction. Housekeeping varies from excellent to very poor. Additional office space would be required in a number of yards to accommodate naval project teams and the additional shipyard staff required. There is plenty of space to erect portable or new buildings. There do not appear to be any significant utilities issues although some are provided by temporary means.

2.8 Design, engineering and production engineering

Shipyards generally have the latest 3D modeling tools, are experienced with a number of different ship types, and frequently undertake new designs. There are, however, a limited number of engineers and draftsmen and all shipyards would need the assistance of an outside agency (or shipyard) to provide specialist knowledge and to handle the volume of work associated with a new first-of-class combatant design. All yards have experience of subcontracting this type of work. Design departments are organized by function rather than ship zone, which is increasing the cost and duration of some of the pre-production processes. However, provided some specialist skills were included, the departments would generally be able to support construction.

Parts listing procedures are quite manual in most yards and coding tends to be basic. Whilst there are examples of world-class shipyard information systems, the degree of systems integration is limited, especially between the CAD, planning and materials control systems which again makes the pre-production processes cumbersome in some yards. All yards have had some experience of weight control, shock, noise and vibration but specialist assistance is generally required for aspects of these.

Only the builders of recently awarded naval vessels have, or are currently gaining, experience with the new ABS Naval Vessel Rules. A greater number have experience of the standards on which the rules are based. There are some key deficiencies in the pre-production processes which, while they would not prevent the vessel being completed, would affect productivity and increase risk. Although there are exceptions in every area and some very good work is done, deficiencies include an almost complete lack of formalized production engineering, scant production engineering design guidance and a limited application of statistical accuracy control.

2.9 Organization and management systems

All yards have a project management function but in most it needs to be expanded to cope with the demands of building a combatant. There is a good degree of experience with government contracts, although not necessarily gained on naval construction. Production tends to be organized on a trade basis. More complex vessels types could be outfitted more effectively if some type of area management were adopted in the later stages of assembly and on-board. Planning systems vary from very good to virtually ineffective. The weakest parts tend to be outfit planning and scheduling. These would need to improve to deal with high outfit ratio vessels. Resources are often not balanced in the schedules and in some yards they are based on durations alone. All yards are currently developing their systems in some way. Most appear to have an effective method of assessing progress. Schedule

adherence can be very good but this is patchy. In some cases, this may be a reflection of the quality of the schedules as much as the ability of the yards to stick to them.

In several yards, subcontracted work is controlled and tracked in a similar way to the yard's own work, which is the best approach. In others, the control of subcontractors needs to become more integrated with the project management systems. QA and QC systems can be very good and are appropriate for the current product mix but they would need to be enhanced in some yards to incorporate some naval requirements. Earned value is calculated regularly although this is generally restricted to the labor aspects. Only two yards have a system that is fully compliant with DFAR. All yards are capable of configuration management. They are also familiar with ESWBS. However, some of the administrative aspects associated with this system are less well developed and not all can report expenditure and progress by system. Although a few yards have almost totally compliant operational security, the others would need to make significant improvements to achieve an acceptable level. There do not appear to be any barriers to do this and some have met the requirements in the past.

2.10 Human resources

Generally, the yards have experienced staff but the levels of academic qualifications and professional registrations are much lower than would normally be seen in a combatant builder. Although there can be difficulty in recruiting enough workers with the necessary skills, there is often a very high level of craft skill in these yards together with a relatively high degree of trade flexibility. Mid-tier yards tend to maintain a core team of workers. The team does not generally have the breadth of skills that are maintained in-house by the larger yards. Some trades, such as electricians, appear to be in short supply but it is common practice to subcontract to make up shortfalls. Local labor pools are often limited and recruitment tends to be nationwide.

Terms and conditions of employment are reported to comply with the standards expected of government contractors. However, they are not always competitive in local communities and in some areas the labor shortage is putting upward pressure on pay rates. While some yards have a loyal and longstanding workforce, there is evidence of a high labor turnover in others, which could indicate that terms and conditions need to be more competitive or that management styles need to be modernized. Forecasting of labor requirements is usually quite good but can be short term in some yards.

In addition to increasing the number of tradesmen and in some cases varying the mix of trades to build higher outfit ratio vessels, most yards would require additional non-touch labor. Individual members of the management and workforce in this sector have far less experience of naval new construction than their first-tier equivalents. However, many have built for the Coast Guard or have undertaken naval repairs within their current employment. Many also have some previous experience with naval construction. It is the general policy to provide training and develop the workforce at all levels and although the standards to be achieved are often well defined, training programs can be ad-hoc. Craft training usually takes place on-site but other types of training are normally subcontracted.

2.11 Purchasing and the supply chain

Most of the yards surveyed have had some experience with procurement for naval vessels but it is quite limited in some. The majority have stated that they understand the requirements. Typically, formal procedures are not adopted to locate and select suppliers and such issues tend to be dealt with as

required. Those yards currently undertaking government work have endeavored to structure their supply base to comply with government requirements. Constraints, such as the availability of suitable suppliers, mean that they often have difficulty in fully meeting the requirements. The performance of the suppliers of major items is monitored quite closely in a good proportion of companies. If the performance of other suppliers is monitored then normally only basic measures are used. Although it could be improved in some yards, all carry out expediting.

Some yards select suppliers with well-established QA systems and then rely on those systems to provide the necessary quality without the burden of a high degree of inspection in the shipyard. In general, goods are checked for damage on receipt and any more detailed QC is carried out by engineering. Many yards have recently improved their treatment of vendor furnished information with the requirements being more closely matched to the product life cycle. However, improvement in this area remains a key priority for most yards.

There are well-established procedures for collating and managing the certification of materials and equipment but only one yard is aware of the NAVSEA T9074-AX-GIB-010/100 material selection requirements, which are referenced in the ABS Naval Vessel Rules. However, there is a universal provision to carry out materials testing either within the company or at a local testing house. All the yards are used to working with subcontractors and to outsourcing but, in some, the procedures are less formal than might be expected.

2.12 Logistics support

All yards have experience with provisioning, providing fitting out services, collating and producing technical manuals, and with crew training. There is no consistent approach to carrying out this work. Some yards have an in-house capability; however, most subcontract this partially or completely.

2.13 Subcontracting

Within reason, any yard can subcontract any aspect of the shipbuilding process and there are examples of shipyards that construct vessels almost entirely using subcontractors. There is a moderate degree of subcontracting in the mid-tier yards so an assessment that includes the capability provided by the subcontractors is probably more representative of the capability of the sector as a whole. The overall effect of the subcontractors' capability on the industry score has been analyzed by making all the subcontracted elements score 2.0. The industry average only increased slightly and for the purposes of this study, the difference is not considered significant. Prime contractors that may be involved in the construction of naval vessels can add significantly to the capability of a mid-tier shipyard. The effect of this has not been examined.

Table 2.1 gives an indication of the profile of subcontracting in the sector by summarizing the number of capabilities indicators in which there is full or partial subcontracting in each group.

Element group	Proportion of capability indicators (%)	
	Subcontract	Partial subcontract
Structural production	5	1
Outfit manufacturing and storage	24	7
Pre-erection activities	1	1
Ship construction and outfitting	1	4
Facilities	0	0
Design, engineering and production engineering	1	12
Organization and management systems	0	2
Human resources	0	6
Purchasing and the supply chain	2	3
Logistics support	29	24

Table 2.1 – Distribution of subcontracted work

There can be more than one reason why a company subcontracts a particular activity. Some additional statistics relating to subcontracting in the mid-tier yards are given below. The proportions quoted relate to the capability indicators and not the proportion of work.

- Approximately 75% of subcontracts occurred because the activity is not part of the core business, there are no in-house skills or there is a desire to mitigate risk.
- About 25% of subcontracts were related to the smoothing of peak labor loads.
- Other organizations in the same group as the shipyard carry out about one in ten of the activities subcontracted.

2.14 Capacity

A high-level capacity model created by FMI has been used to obtain a broad indication of the capacity of the yards surveyed. A much more thorough analysis would be required to accurately define the capacity of the yards. The model compares some key shipyard resources such as building positions, workshop areas and numbers of people, to those that would be required to construct a medium-sized naval combatant within a specific period of time. The model assumes that all of the shipyard resources are available for steady-state, series production of the vessels. It identifies the critical resource in each shipyard and limits the capacity of the yard to that constraint. Assumptions used in the model have been derived from FMI's experience in shipyard development and knowledge of the work content and construction techniques used on typical combatants.

The base vessel has been assumed to be a 400ft mono-hull with work content per unit of volume being slightly less than that of a typical international frigate. A basic build strategy has been assumed and modified according to the specific facilities and practices of each yard. Shipyard productivity figures have been based on actual figures for those shipyards that have provided performance information. For

the remaining yards, productivity has been assumed based on FMI's observations of the shipyard and its experience of shipyard performance.

The model indicates that the capacity of the mid-tier shipyards surveyed is mainly limited by human resources. At the current level of employment, the combined industry capacity is just over five ships per annum at steady-state, with each yard able to build between 0.3 and 1.3 ships per annum. However, a proportion of the industry is not capable of building the vessel in a cycle time that is short enough to be considered reasonable. Also, the capacity in each yard early in a series would be less as the level of productivity achieved could be up to about 50% lower than achieved on later vessels.

Without the labor constraint, the capacity would increase to more than seven vessels per annum at steady-state. However, it should be noted that there is a limited pool of suitable labor and the majority of yards are currently recruiting nation wide. At this level of output, most yards would be limited by their steel preparation and assembly areas and the capacity of some outfit manufacturing shops.

APPENDIX 1 – CNST, ODUSD(IP) AND FMI

The Center for Naval Shipbuilding Technology

The Center for Naval Shipbuilding Technology (CNST) is the Navy ManTech Center of Excellence for shipbuilding and ship repair manufacturing technologies. The CNST mission is to identify, develop and deploy advanced manufacturing technologies in U.S. shipyards that will reduce the cost and time it takes to build and repair Navy ships. ATI in Charleston, SC, manages CNST under a contract with the Office of Naval Research (ONR). Further information is available on the internet at www.cnst.us.

The Office of the Deputy Under Secretary of Defense (Industrial Policy)

The Office of the Deputy Under Secretary of Defense (Industrial Policy) is part of the U.S. Department of Defense. ODUSD(IP) ensures that an adequate defense industrial base exists and remains viable for defense production to meet current, future and emergency requirements. The office also advises the Under Secretary of Defense (Acquisition, Technology & Logistics) on defense industry mergers, acquisitions and consolidation. This includes global investment in U.S. defense firms and other related globalization topics. The office also counsels Defense Acquisition Boards on industrial base and production readiness issues. Further information is available on the internet at www.acq.osd.mil/ip.

First Marine International Limited

First Marine International Limited (FMI) was formed in 1991 to provide specialist consultancy services to the marine industry. Principal clients include shipbuilders and ship repairers, UK and overseas government departments and agencies, and national and international maritime organizations. Members of the FMI team have worked on projects in over fifty countries and were first involved together in the 1970s in the design and engineering of some of the largest and most successful shipyards in the world. The company's expertise includes market research and forecasting; marine industry studies; benchmarking; competitiveness; technology development; upgrading of existing shipyards; design and engineering of greenfield shipyards; and development, implementation and management of shipyard performance improvement programs. Further information is available on the internet at www.firstmarine.co.uk.